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Safety Issues Concerning Installation of Welding Robots

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Abstract

The aim of this research is to summarize the safety measures related to the application of welding robots, as well as to apply them in the ÓE-Cloos Robot Welding Laboratory of Bánki Faculty at Óbuda University. This article describes the safety requirements for welding robot systems, the requirements for commissioning and safe operation. The concluding part of the dissertation presents the preparation and implementation of the installation of a new robot cell in the laboratory.

Keywords*: welding, welding robot, welding robot operation, welding robot installation.*

1. Application of welding robots

Welding accounts for a very significant share of all robot applications, with 30% of the more than one million industrial robots operating worldwide in 2010 being welding robots, and 26% of robot sales in 2010 being welding robots. Within the welding robot application, the two defining areas of application are resistance spot welding and gas-shielded metal arc welding. The two processes are roughly fifty-fifty, and in recent years the ratio has shifted slightly towards arc welding [1]. Nowadays, more and more companies have the opportunity to use welding robots. We have to look for the main reason for their procurement in mass production: the products have to meet the growing demands, both in terms of quantity and quality.

Welding robots make mass production more economical. In order to use the robot properly, it is essential to be able to easily program the workflow: from point to point, the set points must be taught, through which the robot will have to travel in the path specified in each point - point-controlled or some kind of path-controlled. Robot programming can be divided into two major groups.

- during on-line programming, the robot itself is programmed, which requires the presence of the robot: by moving the robot or its model, the path to be traversed by the welding head is taught;
- during off-line programming the production process does not have to be interrupted, the work is done in front of a computer, which can save time.

2. Criteria for factory installation of welding robots

As a general provision, the requirements for machinery are set out in *Directive 2006/42 / EC of the European Parliament and of the Council on machinery* [2]. The installation and operation of machine equipment, such as welding robots, are subject to international regulations, standards and domestic regulations, which have been summarized in the criteria for occupational safety and health.

2.1. The positioning of robots

Once the appropriate robot has been selected, it is necessary to assess the possible location of the robot bearing in mind the specifications.

The floor area of the installed welding workplace must be at least 4 m^2 as prescribed [3]. The choice of the installation location is greatly influenced by the robot's range of motion and work area. Today's state-of-the-art programming methods allow us to restrict the content of the basic configuration of robots, even by disabling various components, so the workspace has a testable software security application.

The size of the immediate danger area around the robot is given in the factory catalogues and is included in the machine manuals.

2.2. Location

Once the selected site meets the basic territorial requirement, it is necessary to consider additional aspects, not only on the basis of work and occupational health, but also on the basis of ergonomic principles.

The lighting in the room must be appropriate for the job, but in all cases must exceed 300 lux. This is the lower limit of proper lighting that does not yet harm the health of the human eye. If the room also has natural light, it is mandatory to provide the window glass with a protective film [4]. The load-bearing capacity of the slab must also be examined, as the robot and the peripherals to be installed on it, the service units, the weight of the workpieces and their servers, represent a significant load.

If the slab is in good condition, the next element is the inspection of the cladding, which must be made of non-slip, non-combustible material, the construction of an even floor is required. If the noise effect associated with the operation of the robot does not exceed 85 dB during work, it is not necessary to provide separate sound insulation, in all other cases it must be ensured.

2.3. 2.3. Delimitation

Mechanical safety components must be determined based on the specification of each component of the installed robotic system. One of the defining elements of these is the determination of the operating range of the robot system, which is greatly influenced by the arrangement of the individual elements of the system, the range of motion of the robot, and the working area. During the installation of welding robots and robot stations, adequate fencing must be ensured so that the operator or any person accidentally or intentionally entering the robot's work area does not suffer any injuries. One possible way to achieve this is to design a mechanical safety fence. The fence can be lattice or full-walled, and can also provide protection against arc light. According to the regulations, an air gap of 150 mm must be ensured between the space delimiting element and the floor [3]. Welding is inevitably accompanied by spattering, which endangers not only the quality of the weld bond, but also the robot and the welding tools. In addition, slag and metal particles generated during the operation of the robot can easily cause a fire in the work area. It is essential to safely place the devices used in the work area and belonging to the work area, to properly separate and cover the cables and wires ensuring the power supply of the robot. A touch test must also be performed by a specialist.

2.4. Arc protection

The need for protection against arc light and its importance have already been discussed in the subchapter entitled Delimitation.

The energy of arc light generated during welding consists of three components: ultraviolet radiation, visible light, and infrared radiation. Radiation beyond the violet can cause inflammation of the cornea of the eye. Studies have shown that the intensity of such radiation is proportional to the square of the intensity of the welding current, above 50 A.

Damages the retina through the effects of visible radiation and can cause vision damage by initiating photochemical processes. The danger is exacerbated by the accumulation of harmful effects in the eye. The harmful effects of infrared radiation on the eyes are also a consequence of the radiant heat effect. Occupational safety equipment, if inadequate or not used, can cause cataracts, corneal, retinal or ocular lens damage, corpus luteum atrophy, partial blindness, extreme, severe loss of vision in severe cases.

In order to eliminate and reduce the biological effects of light radiation associated with welding, the skin surface must be protected by covering and an eye protection filter used. The grade of the protective filter to be used is determined by the welding process, the amperage, the intensity of the energy source, the wire, the base, and auxiliary material, and the ambient lighting. It is a generally accepted rule that a stronger filter should be used in the case of a more powerful heat source or in less favorable ambient lighting. Arc-light protection can be provided by a full plate or safety grating frame, a robotic station with a protective curtain for arc welding. On the

serving-side of the robot station, mobile arc-light protection can be applied, which can be

- a sun visor wall mounted on a positioning device, which rotates together with the two workstation positioning devices and separates the service side in the working position from the interior where the robot welds;
- security door, which also serves as light protection;
- automatic sun protection curtain, manually retractable sun protection curtain [5].

2.5. Ventillation

Ventilation and removal of harmful substances generated during welding must be ensured for ergonomic work. Suitable welding and filtering systems must also be used for welding robots, the choice of which depends on the welding process and the robot station. The extraction-filter device can be a central extraction-filter device, a mobile extractor placed on or directly next to the welding head, or a suction hood mounted above the robot.

The location, size and design of the suction hood depends on the layout and construction of the individual robot or the robot system used in the given plant. Starting and stopping the suction unit is usually automatic, it is advantageous if it is integrated in the control of the robot system [5].

2.6. Fire Protection

Of course, fire safety regulations must be observed when working in the room. These regulations are contained in the applicable laws and regulations. Where possible, cables shall be covered with a cable duct to prevent the cables from catching fire and the fall of the inspector or worker during maintenance or after the necessary emergency shutdown. If shielded gas welding takes place in the room, various individual gas cylinders can be placed near the workstation, be it argon or carbon dioxide, the cylinders need to be fixed.

In addition to gases, a potential source of danger is the previously mentioned glowing metal particles. We protect against it by covering the cables with cable ducts. For safety reasons, it is essential to have a carbon dioxide fire extinguisher on site.

The escape plan must also be displayed, the route marked, the exit marked accordingly, and it must be possible to keep it open or easily openable.

3. Comissioning of welding robots

After installing the robot, the work can start if the occupational safety commissioning has taken place. During the procedure, the occupational health and safety specialist examines whether the suitability of the robot has been verified and whether the employer has complied with the previously explained criteria. The employer is required to establish operational regulations. In order to operate a welding robot, it is necessary to obtain a welding robot programming license, which takes place within the framework of a course. The following must be included in the commissioning report:

- date of commissioning;
- the serial number;
- technical and safety conditions item by item;
- official permits;
- all financial commitments related to the invested asset (eg logistics fees);
- expected lifetime;
- the name of the receiving factory, factory department, responsible person;
- the date of receipt [6].

The robot's data sheet and description include maintenance information, as well as the individual parts, their service life, and periodic replacement requirements.

Maintenance and repairs may only be carried out by a person with a specialist qualification and authorized by the manufacturer in accordance with the operating instructions issued by the manufacturer [4]. Nevertheless, the user can be expected not to be completely lazy about robot specifications, as he should be familiar with the protocols for in-house training or in case of problems. During periodic inspection shall verify:

- the surfaces of the robot, searching for damage;
- electrical cables;
- the supply pipes during gas shielded arc welding;
- the power supply equipment;
- the emergency stop mechanism;
- proper operation of the programming interface;
- the condition of the workpiece clamps, the target equipment [4].

Following maintenance or repair, the installer cannot be held liable in the event of a fault, as the person in charge of maintenance or repair must make a formal, documented statement of the action taken. The authenticity of the maintenance report is entirely the responsibility of the verifier.

3.1. Occupational safety installation criteria

Requirements for the use of a welding robot system can be derived from the provisions of the Occupational Safety and Health Act and the Welding and Safety Regulations [7]. According to 18. §. (3): „Work equipment may only be put into service and put into service if it meets the requirements for safe and safe work and has an EU declaration of conformity for the work equipment as a product, as defined in separate legislation. or any other document attesting conformity (eg certificate).” [7] In this regard, the European Parliament and the Council2006/42/EU – Evaluation of Machinery Directive [2] contains the defining requirements in accordance with the relevant MSZ EN ISO standards, which are as follows:

- MSZ EN ISO 12100:2011 Safety of machinery – General principles for design. Risk assessment and risk reduction ;
- EN ISO 10218-1:2011 Robots and robotic devices. Safety requirements for industrial robots. Part 1: Robots
- MSZ EN ISO 10218-2: 2011 Robots and robotic devices. Safety requirements for industrial robots. Part 2: Robot systems and integration;
- MSZ EN ISO 13857:2008 Safety of machinery. Safety distances to prevent hazard zones being reached by upper and lower limbs;
- MSZ EN ISO 13850:2016 Safety of machinery. Emergency stop function. Principles for design.

During the safety commissioning of welding robot systems, the conformity assessment must also cover the management of the risks associated with welding. [5].]. This means that during welding, the robotic system consists of at least two separate application units such as:

- mechanical equipment (robot or manipulator) for the coordinated movement of the welding gun and / or workpiece, which must meet the requirements of the MD Machinery Safety Directive and harmonized standards;
- arc welding equipment, which must comply with the Low Voltage Electrical Products (LVD) and Electromagnetic Compatibility (EMC) Directives, the requirements of the relevant harmonized standards and the requirements for welding tools, such as the Welding Safety Regulations (HBSZ) [7].

Standards for arc welding equipment:

- 2014/35/EU – LVD Low Voltage Directive;
- 2014/30/EU Electromagnetic. Compatibility (EMC) Directive:
- MSZ EN 60204-1:2006 Safety of machinery. Electrical equipment of machines. Part 1: General requirements;
- MSZ EN 61000-6-2:2007/AC:2005 Electromagnetic compatibility (EMC) Part 6-2:
- Generic standards. Immunity for industrial environments;
- MSZ EN 61000-6-4:2007/A1:2011 Electromagnetic compatibility (EMC) - Part 6-4:
- Generic standards. Emission standard for industrial environments ;
- MSZ EN 60974-1:2013 Arc welding equipment – Part 1.: Welding power sources;
- MSZ EN 60974-10:2008 Arc welding equipment. Part 10: Electromagnetic compatibility (EMC) requirements.

In order for a welding robot system to be placed on the market, the manufacturer must affix the CE marking, which certifies that the robot system (both separate units indicated above) complies with all the relevant regulations.

4. Óbuda University–Cloos robotic welding station

4.1. History

On 26th of October in 2009, after successful cooperation with the CLOOS representative of Crown International Kft., the Bánki Donát Faculty of Mechanical and Safety Engineering at Óbuda University, was enriched with a Robot Welding Laboratory

The stated goal was to introduce modern industrial tools in education as well as to promote research.

For the operation of the robot welding station established and operating in the Népszínház street building, Crown International Kft. has continuously provided us with new, complete robot welding cells for the last 10 years and has taken care of their operation.

4.2. Installation of new welding robot system

In 2019, as a continuation of the previous modernization process, CROWN International Kft. planned to donate a new welding robot system, the installation tasks of which we prepared. The new welding system will provide an additional opportunity to strengthen the training and research potential, so that the Faculty can meet the expectations of the economy, Industry 4.0, the challenges of digitalization. Robotic systems, robotic manufacturing, and robotics applications play an

important role in the training program of the Faculty, in the curriculum of mechanical engineering and mechatronics engineering. After taking over the new welding robot and its peripherals, the Department of Materials Technology of the Institute of Materials and Manufacturing Sciences, which supervises the robot station, started preparations for the installation plan, the design of the robot station, and the creation of safe operating conditions. In terms of its function, the robot system is used for demonstration laboratory purposes for mechanical engineering, mechatronic engineering, as well as international welding engineer and welding technology students, in addition to this it performs research tasks.

In addition, the CLOOS Representation in Hungary plans to organize training for partners, employees, and students at our Faculty. The room opens from the "A" part of the Faculty building, has a high ceiling, both windows face the courtyard. The floor is suitable for the specialised job, providing enough light for ergonomic work.

The CROWN International Kft. provided the following equipment for the design of the new robot station:

– QRC-290 robot-arm;
– Quineo NexT 452 DC power source;
– QC9 Basic Quriox Controller;
– WP-TS Rotating and tilting manipulator.

Upon receipt of equipment, the installation was prepared and carried out taking into account the regulations and aspects described in Chapter 2. During the placement of the robot, we had to take into account its working area, as well as its ability to move 360 degrees.

Due to the size and capabilities of the space, the robot had to be installed close to the wall, so it became justified to delimit the robot's workspace. Due to the demonstration function of the laboratory, ten important aspects highlighted to the proper demarcation of the robot

For practical reasons, a lattice fence with a sliding gate was designed. During the design of the fence, the following criteria were defined due to the limited space available:

– the sliding gate had to be designed in such a way that both wings could be pushed in 600 mm behind the wall element, with the exception of the material thickness and the size of the stops an opening of 1100-1200 mm had to be provided;
– forming an angled bevel at the control cabinet, on top of the control cabinet, its size is 1350 mm high (equal to the height of the frame) and 1000 mm wide.

During the design of the arc-light protection, it would have been possible to place a work window at the full-walled fence and at the sliding gates, but in order to ensure a better observation during the work process, we opted for a lattice design. Adequate protection is provided by the use of an LED darkened head shield. The laboratory is suitable for conducting individual experimental or small group sessions at the same time. In order to ensure protection against the arc light, it has also become necessary to cover the windows of the ground floor room opening to the courtyard with an appropriate degree of darkening film.

The previously purchased KEMPER 1700 m^3/h air extraction system was available for the extraction of the generated welding fumes, before the use of which we took to contact the manufacturer to request the certification of the equipment and the commissioning of the device.

The wall-mounted, suction equipment provides the removal and filtration of unwanted gases, vapours, and carrier elementary particles. Robotic use is regulated, subject to authorization, so it can

Figure 1. *The installed robot system with the welding robot and power supply.*

be ensured that unauthorized persons cannot enter the laboratory area and the equipment is not operable.

5. Summary

In our research, after the legal regulation of the installation of a robot system and the presentation of its European and domestic legal system, we reviewed several criteria of the factory installation of welding robots and the possibility of safety regulation.

The conditions of the application were described in relation to the Cloos Robot Welding Laboratory of the Donát Bánki Faculty of Mechanical and Safety Engineering at the Óbuda University. A further aim of the activity is to create a regulation after the commissioning procedure, which summarizes the criteria for safe work and what to do in case of an emergency.

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